Topography of Europan Brown and Gray Mottled Terrains from Galileo Images at Low Sun Illumination. J. E. Klemaszewski[1], R. Greeley[1], and the SSI Team, [1]Arizona State University Dept.of Geology, Box 871404 Tempe, AZ 85257.

Mottled terrain was identified as a fundamental geologic unit of Europa by Lucchitta and Soderblom [1] based on 2.0 km/pixel Voyager 2 images. Understanding the characteristics of mottled terrain and its geologic relationships should improve our understanding of its formation and role in the evolution of Europa's surface. Galileo images of mottled terrain at low sun illumination provide new information about its topography. Linear ridges are observed to be disrupted by plateaus in the brown mottled terrain. A correlation of circular low-albedo features between Voyager 2 and Galileo data reveals that they often correspond to negative relief. Hummocky topography similar to brown mottled terrain is seen to surround large low-albedo spots north of the brown mottled terrain. Topography of gray mottled terrain is characterized at resolutions up to 0.44 km/pixel. Cross-cutting relationships of linear ridges in the gray mottled terrain allow for a determination of relative ages of some of its features.

VOYAGER OBSERVATIONS

Mottled terrain is one of the two principle geologic units on Europa seen in Voyager 2 images based on morphology, albedo and structural style [2,1], and classified as UV-bright by Johnson et al., [3]. Lucchitta and Soderblom [1] subdivided mottled terrain into two types on the basis of their colorimetric properties: brown and gray mottled terrain.

Brown mottled terrain is characterized by pitted, hummocky topography and numerous low-albedo patches that range in size from a few tens of km down to the limit of resolution [1]. Domes, ranging in size from <1 km to >30 km, were noted within mottled terrain in images obtained under low sun illumination [2]. Linear ridges are less abundant in mottled terrain; they are faint, disappear, or are segmented [4,1,2]. The normalized reflectance spectra of brown mottled terrain are similar to those of brown materials that occur in small spots and large patches [1].

In comparison, gray mottled terrain displays albedo characteristics similar to both brown mottled terrain and plains units. Like brown mottled terrain, gray mottled terrain is comprised of low-albedo patches, ranging in size from a few km to several tens of km, which are transected by numerous intact linear ridges. The normalized reflectance spectra of gray mottled terrain closely resembles those of the dark and bright plains, and bright craters [1]. Topographic information regarding gray mottled terrain was unavailable, as it was not present at or near the terminator in any Voyager images.

GALILEO OBSERVATIONS

Topography and structures within mottled terrain are visible in images at a resolution of 1.6 km/pixel, taken during Galileo's first orbit. In these first regional images, mottled terrain is located along the terminator between 5 and 18 degrees north latitude, and 160 and 170 degrees west longitude. This area is part of the type locality of brown mottled terrain [1] seen in Voyager 2 images. Galileo images reveal that this area contains numerous pits and depressions (also noted by Lucchitta and Soderblom [1]) that range in size from a few km to about 10 km in diameter interspersed with "mounds" of similar size, giving the terrain a hummocky appearance. Several large plateaus are also visible, ranging in width from a few km up to a few tens of km, and up to nearly 100 km in length. The margins of these plateaus are sharp in some locations, but are gradational in other instances. Several plateaus are bounded by linear ridge segments up to a few tens of km long. The margin of a plateau at 8N, 168W partially envelops a circular depression, giving the appearance of having formed around it. A similar structure, other plateaus and hummocky topography are visible near 85N, 307W and may indicate the presence of mottled terrain near polar latitudes, but this cannot be confirmed from Voyager 2 images. Although the topography in brown mottled terrain may be an expression of thermal activity on Europa, it is not clear at this resolution if features (e.g. plateaus and depressions) are endogenic or exogenic.

Most ridges that enter brown mottled terrain in this area terminate or are disrupted, often by plateaus. For example, a ridge extending from a triple band at 8N, 168W, although disrupted for distances up to 50 km, can be traced into the mottled terrain for approximately 150 km. The segments of the disrupted ridges range in length from the limit of resolution up to a few tens of km. There are, however, occasional exceptions. A ridge at 5N, 165W remains intact for over 100 km, and sits stratigraphically on top of the topography of the mottled terrain.

The brown mottled terrain imaged by Galileo under low sun illumination was previously imaged by Voyager 2 under high sun illumination at 2.0 km/pixel, providing an opportunity to compare albedo features with topography at nearly the same resolution. Three large low-albedo spots located in bright plains about 5 degrees north of the brown mottled terrain (near 22N, 165W) can be seen in Voyager 2 images. These spots were seen by Galileo to be depressions, and were observed to be in an area with hummocky topography with a gradational margin. This relief extends to the east for a distance of approximately 40 km before terminating at a smooth plains unit. Several other circular to subcircular low-albedo features located within the brown mottled terrain are also observed to have negative relief. The largest of these corresponds to a ~25 km diameter circular depression located near the terminator (12N, 165W). The circular crater at 8N, 168W also corresponds to a circular low-albedo spot. These depressions, while circular, do not appear to have raised rims or ejecta

blankets, but these could have been modified by the formation of the brown mottled terrain. For example, the relationship of the plateau margin with the outer edge of the depression may indicate the previous existence of a raised rim that has since relaxed.

Detailed topography of gray mottled terrain was first revealed during Galileo's third orbit in images with resolutions of 0.85 and 0.44 km/pixel under low sun illumination, and is characterized below. The first image covers an area 24 km wide by 340 km long to the northwest of Cilix, a 25-30 km diameter knob in the gray mottled terrain located near 4N, 190W. The second image covers a 40 km by 75 km area, near 10S, 190W. In overall appearance, the topography of the gray mottled terrain is smoother than the brown mottled terrain, lacking the hummocky appearance of the brown mottled terrain, but exhibiting some positive relief. Two plateaus are clearly visible in these images. One plateau, 5 km by 10 km, is visible in the southern image, and corresponds to a low-albedo spot in Voyager data. Ridges terminate sharply at the plateau margin, which appears to have covered them. The top of the plateau is rough; it appears to contain small knobs and mounds less than 1 km in diameter. A second 5 km-wide plateau is also visible in the bottom of this image, approximately 40 km from the margin of the gray mottled terrain as defined by Lucchitta and Soderblom [1]; however, the contact between the gray mottled terrain and plain units in the Voyager 2 data is gradational. The plateau has a smooth top and is bounded on one side by a linear ridge--this kind of relationship is also observed in the brown mottled terrain. Other plateaus are observed in gray mottled terrain in the 1.6 km/pixel coverage. These plateaus, 15 km wide and up to 80 km in length, are visible approximately 50 km to the south of Cilix. Three knobs, 3 to 6 km in diameter, are also visible near 10S, 190W. A fourth knob, approximately 15 km wide with a concave top corresponds to an oblong low-albedo feature in Voyager 2 images.

Linear ridges are more apparent and less disrupted in the gray mottled terrain than in the brown mottled terrain, which allows a determination of the relative ages of some features in the image from their cross-cutting relationships. Approximately five linear ridges with steeply sloping sides and distinct margins are visible in these images. Hundreds of other ridges with lower relief and gently sloping sides, which gives them a relaxed appearance, are visible in the gray mottled terrain. The sharp, distinct ridges cut across the flattened ridges, without exception. The flattened ridges, with two exceptions, are cut by the three small knobs. The large concave knob is cut by only one ridge. The knobs and distinct linear ridges do not intersect, making their relative ages indeterminate.

SUMMARY

Brown mottled terrain, rather than preventing the formation of linear ridges, appears to disrupt existing linear ridges. Ridge segments often terminate at plateau margins; this gives the appearance that the ridges were disrupted by the later-forming plateaus. The intact ridges which sit stratigraphically on top of the plateaus and the hummocky topography of the brown mottled terrain are probably among the youngest features in this region, and provide an indication that linear ridges can form in mottled terrain.

A relationship may exist between some types of low-albedo spots and brown mottled terrain. Low-albedo spots north of the brown mottled terrain are located in hummocky topography similar to brown mottled terrain. This, coupled with their similar normalized reflectance spectra [1], may indicate that they are formed by a related process, but perhaps at different scales.

Circular low-albedo features in the brown mottled terrain observed in Voyager data that are seen to have negative relief in Galileo images may be modified impact craters or palimpsests. Their lack of raised rims and ejecta blankets does not rule out an impact origin, as these could have been modified or destroyed in formation of the brown mottled terrain. If they are impact craters, their presence may help delimit the age of the brown mottled terrain and also help to identify other potential impact craters on Europa.

Morphology and cross-cutting relationships indicate that gray mottled terrain has evolved over time. The relaxed appearance of the flattened ridges, coupled with the observation that they are cut by most other features leads to the interpretation that they are among the oldest features in the gray mottled terrain. The knobs, distinct ridges, and plateaus followed in an indeterminate sequence.

The relationship between the gray mottled terrain and brown mottled terrain can not be determined with these data. The brown mottled terrain and the gray mottled terrain in these images contain similar features, but in different amounts. The brown mottled terrain has a rougher topography, more plateaus, and fewer intact linear ridges than the gray mottled terrain. These observations could be intepreted as a difference in age, a difference in the amount of development between the terrains, or both. Unfortunately, the differences in resolution and in size of the areas imaged necessitates further data to determine the relationship between brown and gray mottled terrains.

REFERENCES

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